BABY B'AIR FLIGHT VEST

DECELERATION SLED TEST ANALYSIS

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CONTENTS

BACKGROUND

The Baby B'Air™ Flight Vest (BBFV) is a Lap child Safety Restraint Vest (LCSRV). Currently, Digital Three, Inc. (DBA Baby B'Air) is working with the United States Congress and Aviation Service Providers to improve the safety of lap children through evaluation and promotion of the BBFV safety merits.

In particular, the LCSRV may be used, as part of a cabin Safety Management System [a], to mitigate risk of injury to child and guardian (adult) and other occupants during both in-flight turbulence and (takeoff and landing) survivable crashes by constraining the lap child to a region close to the adult, thereby preventing or lessening severity of unexpected turbulence and impacts in the event of a survivable crash so as to allow for quick retrieval of a lap child and egress from the aircraft.

PURPOSE

This document is intended to assess the results of the Kettering University Crash Safety Center Deceleration Sled Test [b].

The following safety considerations are made:

1. Exacerbation of Adult injury modes
2. Adult Crush Zone (ACZ) interactions
3. Vest Retention of child

ANALYSIS APPROACH

The adult only sled test 'maximum measured values' ([b], Table 5) provide a baseline for evaluating the relative effect of an unrestrained and a restrained lap child on the three major adult injury modes:

- Head Impact (linear acceleration)
- Chest Compression (linear acceleration)
- Lumbar Torsion/Compression (moment/force)

The graphical data ([b], Appendix B) along with the test videos provide a basis for defining the severity of adult-child interaction; while the test photos ([b], Appendix A) identify the seatback interaction points (chalk marks) and provide visual data for assessment of the post-crash BBFV integrity.

ANALYSIS

The following Configurations are presented and analyzed herein below:

1. Single Row Testing
2. Two Row Testing – Centerline Child Placement
3. Two Row Testing – Offset Child Placement

SINGLE ROW TESTING

The single row scenario allows the adult to fully pivot about the lap belt, causing extended head impact accelerations in both downward and rearward (z,-x) directions. During this test, the head impact criteria (HIC) exceeded the maximum value identified in the Performance Standards ([d], paragraph 6.2). In the video, the child makes contact with the adult resulting in a slight reduction in the Adult rotation; thereby reducing the maximum measured adult HIC value and chest accelerations.

It should be noted that this scenario was simulated and reported in the Baby B'Air Performance Assessment [c] with similar kinematic results and included the finding that the unrestrained child achieves a kinetic energy approximately eight times greater than that of the tethered child. Unlike the sled test, the simulated model included adult arm forces that restrained the child. These forces, in combination with the adult-child interactions, resulted in minimal increases in adult excursion and kinetic rotational energy (i.e. potential injury).

Also in the Performance Assessment, the forces in the vest lap belt loop were determined to exceed 500lb during the single row testing. This was far in excess of the applied 300lb force, in early Lap child Retention testing [e], that resulted in vest tearing. The single row Sled Test ([b], Figures A19 through A28) corroborated this finding, showing significant tearing of vest and restraining straps. Despite this result, the vest satisfied the intended purpose of keeping the lap child in close proximity to the Adult.

TWO ROW TESTING: CENTERLINE CHILD PLACEMENT

The two-row scenario interrupts the full adult pivot with the head impacting the forward row seatback. The adult head chalk mark indicates an impact at the top of the seat, directly above the stowed tray table, and, while significantly increasing the peak head acceleration, results in a reduced HIC. As with the single seat row test, interaction with the lapchild, observable in the chest acceleration graphical data at 125ms, results in a decrease in the adult HIC. In this case, however, the interaction is more significant and provides an indication that the lapchild is maintained in the ACZ. Comparison of the restrained and unrestrained lapchild data and chalk marks show that this interaction is worse for the restrained lapchild. The test video suggests that this difference is due to the unrestrained lapchild partially exiting the ACZ between the Adult knees and seatback.

TWO ROW TESTING: OFFSET CHILD PLACEMENT

The two-row scenario is modified with the lap child set to one side of the adult. This scenario results in adult head and chest accelerations that are nearly identical for the adult only and restrained lap child (i.e. very little adult-lap child interaction). However, the unrestrained lap child graphical data suggests that the lap child moved partially into the ACZ without benefit of exiting between the Adult knees and seatback (as was the case in the centerline positioning).

CONCLUSIONS

EXACERBATION OF ADULT INJURY MODES

The frontal crash sled tests and previous simulation results provide evidence that the adult injury modes (head impact, chest compression and lumbar compression/torsion) will not be effected by the inclusion of a lap child, either restrained or unrestrained. However, the high kinetic energy achieved by an unrestrained lap child in the single row test scenario is an indication of serious potential injury to other cabin occupants.

ADULT CRUSH ZONE (ACZ) INTERACTIONS

Without lap child instrumentation and safety criteria, an acceptable level of adult-child interaction cannot be assessed. The lap child centerline and offset sled tests demonstrated both that a child fully exiting the ACZ and a child placed outside the ACZ can significantly reduce the level of interaction; with the least interaction occurring when a restrained child was placed in an offset position (e.g., to the side of the adult).

VEST RETENTION OF CHILD

For the two-row testing, both the restrained and unrestrained lap child were maintained in close proximity to the adult. The unrestrained child was retained due to the narrow pitch, slanted seat configuration and a linear acceleration that directed the lap child straight into the seatback; however, offset accelerations that direct the lap child at angles to the seatback will result in lap child movement away from the adult. Under these offset accelerations, the restrained lap child is expected to stay in close proximity to the adult even when the vest lap belt loop forces are large enough to tear the vest.

An additional property of a BBFV is the capability to manipulate the forces and moments applied to the lap child to reduce risk of injury (e.g. control the path and angle of the lap child during trajectory).

REFERENCES

[a] Safety Management Systems for Aviation Service Providers,
FAA Advisory Circular (120-92B, August 2015)

[b] Kettering University Crash Safety Center, Baby B'Air Flight Vest Deceleration Sled Test Final Report, October 6, 2016

[c] Baby B'Air Flight Vest Performance Analysis,
T. Malay, November 2007

[d] Performance Standard for Standard Seats in Civil Rotorcraft, Transport Aircraft, and General Aviation Aircraft AS8049B
SAE Aerospace Standard (Revised January 2005)

[e] Strength Test of Digital Three's Child Restraint Device
CB Dynamics, Incorporated (September 1998)